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HYDROCHEMICAL CHARACTERISTICS OF THE SURFACE WATER OF THE ARCTIC BASIN

V.P. Rusanov

The main factors controlling the chemical composition of the water masses of the Arctic ocean are water exchange with the Atlantic and Pacific oceans, river runoff and freezing and melting processes. The influence of Atlantic water is most manifest in the Eurasia sub-basin, whereas the hydrochemical regime of the Amerasia sub-basin is determined largely by water exchange with the Pacific. Annual variations in the volume of runoff from land and the amount of Atlantic and Pacific water entering the basin bring about considerable changes in the areas in which waters with a given chemical composition occur. However, the main features of the distribution of hydrochemical characteristics in the Amerasia and Eurasia sub-basins and in the central part of the basin over the Lomonosov Ridge are fairly constant.

After summarizing all the data gathered so far on the hydrochemistry of the water masses we were able to divide the waters of the Arctic Basin into chemical-oceanographic regions and establish the long-term average characteristics for each type of water [Rusanov, 1975a]. It is the surface waters of the Arctic Basin that have the most complex composition, since that is where the hydrological, physicochemical and biological processes are most intense. They comprise waters from

various sources: the Atlantic, Pacific, rivers, seas, meltwater. Fig. 1 depicts the boundaries of the principal types of surface water in the Arctic Basin separating surface waters with similar values of the key characteristics: temperature, salinity, oxygen content, pH, silicic acid, phosphates. The long-term average values of the hydrochemical characteristics for each type of water are given in Table 1.

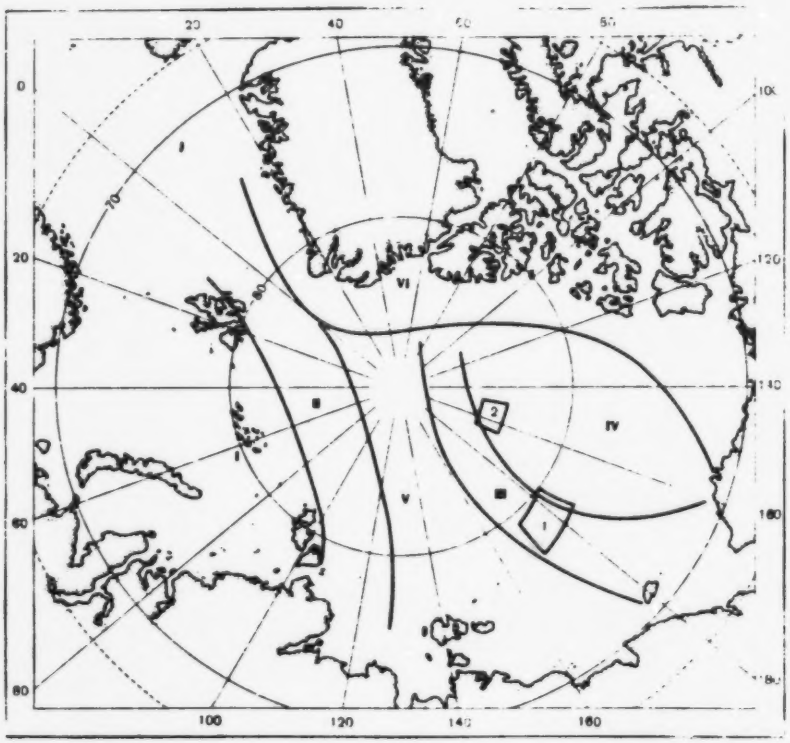


Fig. 1. Chemical-oceanographic classification of Arctic Basin surface waters.

I - Spitsbergen type; II - Severnaya Zemlya type; III - Wrangel type; IV - Canadian type; V - central type; VI - Canadian-Greenland type; 1 - area covered by drifting station "Severnyi polyus-20"; 2 - area covered by drifting station "Severnyi polyus-22"

The surface waters of the Arctic Basin can be divided into three distinct main groups: Amerasian (Wrangel and Canadian types), Eurasian (Spitsbergen and Severnaya Zemlya types), and median (central and Canadian-Greenland types).

The differences between the surface waters of the Amerasian and Eurasian groups can be easily traced by each of the seven classificatory characteristics, which makes it possible to establish the boundaries of their distribution over the Arctic Basin. Less pronounced are the properties of the waters of the median group which are marked by intermediate values of the hydrochemical characteristics. But as these waters are characteristic of a well-defined area extending over the Lomonosov Ridge, they form a separate group. The differences in the hydrochemical properties of the three main groups of surface water types are well marked between all the water masses of the Arctic Basin (Fig. 2). The groups not only give an idea of the areas in which the different types of surface waters are formed, but also reveal the main directions in which transport takes place.

p. 16

p. 19

The waters of the Eurasian group, formed at the boundaries of the Arctic and Atlantic oceans, occupy the entire Eurasia sub-basin. They are characterized by northeasterly transport from the direction of the Greenland, Barents and Kara seas. This applies not only to the surface water masses but to the others as well. Because of the close genetic relationship of the main water masses of this group, the vertical distribution of all the hydrochemical characteristics is marked by an absence of abrupt changes in values at the interfaces between them and of pronounced extremes from the surface to the bottom (see Fig. 2).

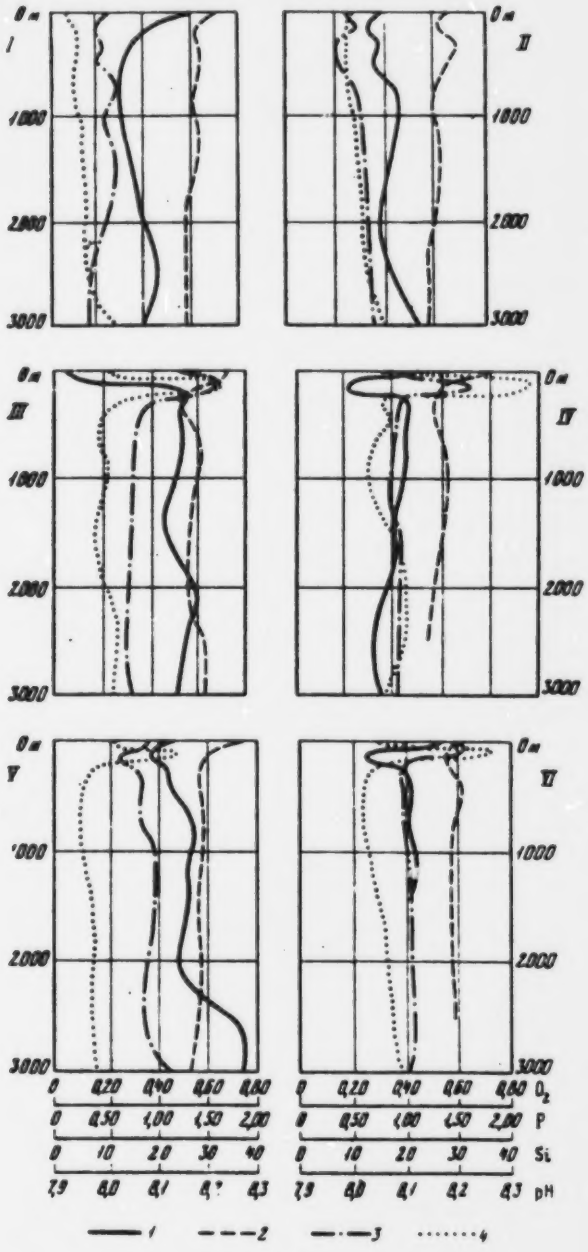


Fig. 2. Typical distribution curves of oxygen (mg-at/l), phosphates and silicic acid (μg-at/l) and pH values. (Numbers denoting types of waters are the same as in Fig. 1)

1 - pH; 2 - oxygen; 3 - phosphates; 4 - silicon

main types of surface water in this group are genetically homogeneous, since Atlantic water lies at their base. However, owing to the different routes by which they reach the Arctic Basin there are differences in their physical and hydrochemical properties. Surface waters of the Spitsbergen type, which enter the basin through the Barents and Kara seas, are on average colder, richer in oxygen and have higher pH values than surface waters of the Novaya Zemlya type which flow straight into the basin from the Greenland Sea. All the waters of this group have a low content of silicon (less than 300 µg/l) and phosphates (range 10--20 µg/l).

The Amerasia sub-basin is marked by northwesterly transport of water masses at all depths and has a more complicated vertical distribution of hydrochemical characteristics due to the genetic diversity of the water masses, the pattern of circulation and water exchange, the bottom topography and other local features of the sub-basin.

Surface waters of the Canadian type are formed mainly during summer over the vast area of the Beaufort sea. The considerable share of meltwater means that these waters have the lowest salinity in the entire Arctic Basin and a low content of biogenic elements [Rusanov, 1974]. Rapid cooling of the surface layer at the beginning of winter leads to oversaturation with oxygen. The prolonged isolation of the surface water from the atmosphere in winter and the low expenditure of oxygen on oxidation processes under low temperature conditions helps the preserve the excess oxygen.

Surface waters of the Wrangel type are formed in the Chukchi sea under the strong influence of Pacific waters, which means that they have a higher salinity and also a greater content of biogenic elements

due to the specific biological and hydrochemical conditions obtaining in the Chukchi sea. Although the oxygen content of the Chukchi sea waters is as high as 115% during the biological summer, saturation of surface waters of the Wrangel type is only about 100%. This is due to the considerable expenditure of oxygen on the oxidation of organic matter removed from the Chukchi sea by the surface waters. p. 20

As can be seen from Fig. 1, surface waters of the Canadian type spread far to the north from their point of formation, occupying the entire Canada Basin and the region of anticyclonic circulation. Surface waters of the Wrangel type spread northwest from their source area, following the general direction of flow of water and ice from the southern parts of the Amerasia sub-basin. However, owing to the strong flow of waters of the Eurasian group from the west, they deviate from the axis of the Transarctic Current and extend in a narrow band almost strictly northward, reaching the pole region and being quickly transformed around the periphery by mixing with waters of the Canadian and central types.

The vertical distribution of hydrochemical characteristics in the Amerasia sub-basin is controlled mainly by the influence of waters of Pacific origin flowing in through the Bering Strait. Within the Amerasian group, as in the case of the surface waters, there are distinct Canadian and Wrangel types of intermediate water occupying a layer extending from 50 to 150-250 metres [Gudkovich, 1955; Nikiforov et al., 1966]. They share a biogenic element maximum (1000-1500 µg Si/l, 40-60 µg P/l, and for nitrates over 200 µg/l) at depths of 100-150 m. and a corresponding minimum for oxygen and pH. The high content of biogenic elements in the intermediate waters of this part of the Arctic

Basin is due to the way in which the diatom flora has developed in the Bering and Chukchi seas [Zhuze, Semina, 1955]. As the result of regeneration during the winter the waters of the Chukchi sea are enriched with silicon to the highest concentrations in the entire Arctic ocean, exceeding 2000 micrograms per litre in some years. From these regenerated waters an interlayer of Pacific waters is formed on the shelf of the Chukchi and East Siberian seas [Rusanov, Belyakov, 1972] which can be traced throughout the Amerasia sub-basin at depths ranging from 75 to 150-250 metres [Treshnikov, 1960; Gushchenkov, 1964; Belyakov, Rusanov, 1971].

The Canadian type of intermediate waters is formed mainly on the continental slope of the Chukchi sea from Bering sea and Chukchi sea waters transported by the Alaska and Long branches of the Pacific Current. It is characterized by higher concentrations of biogenic elements (see Table 1) and great thickness of the Pacific water interlayer. Intermediate waters of this type occupy almost the entire Amerasia sub-basin from the Chukchi sea to the northwest coast of Greenland.

Intermediate waters of the Wrangel type, which form on the continental slope of the East Siberian sea from waters transported there by the Long branch, form a narrow strip along the eastern part of the Lomonosov Ridge from the de Long Archipelago to the Pole. The silicon content of these waters is far lower, and the thickness of their interlayer is reduced to 50-75 m. p. 21

It should be noted that in the areas in which the intermediate waters of the Amerasian group occur there is an enhanced silicon content in the lower-lying water masses - in the Atlantic and especially the abyssal and bottom waters. This is evidently due to

mineralization of the remains of diatoms sinking into the lower layers. The absence of significant pycnoclines between the water masses, starting with the Pacific and ending with the bottom water, facilitates this process. As a result the remains of dead diatoms accumulate in the abyssal layers where they undergo further dissolution which leads to the enrichment of these waters with silicon. In spite of this there is no increase in the concentration of phosphates in the lower layers, although their rate of regeneration is much higher.

Surface waters of the central type of the median group are formed in the northwest part of the East Siberian sea and in the northeast part of the Laptev sea. There is a large contribution from continental runoff (the rivers Lena, Indigirka and Kolyma). This explains their low salinity and the increased content of biogenic elements. The annual distribution zone of these waters in the Arctic Basin fluctuates considerably depending on the volume of runoff from the land, the rate of inflow of waters of the Eurasian group from the west and waters of the Amerasian group from the east. Acting as it were as a buffer between the flows of these large groups of waters, surface water of the central type extends in a narrow strip northward into the area of the Arctic Basin which overlies the Lomonosov Ridge.

This type of surface water corresponds to upper intermediate waters which are markedly transformed waters of the Pacific interlayer containing maximal concentrations of biogenic elements, from a depth of 100-150 m (in the Amerasia sub-basin) to 75 m. The lower boundary of the Pacific waters beomes much more clearly defined, while the upper one becomes more diffuse so that surface waters of the central type are enriched in biogenic elements and their salinity is increased. It

should be pointed out that the Pacific interlayer does not come to the surface in the Lomonosov Ridge area every year. It obviously depends on the rate at which the Pacific water in the intermediate layer and the underlying Atlantic water flow into the region.

As regards the surface and underlying intermediate waters of the Canada-Greenland type, in terms of their geographical position and hydrological and hydrochemical characteristics they are the result of mixing of transformed waters of the Amerasian group and of the central type. The area of distribution and characteristics of this type of water fluctuate markedly from year to year depending on the rate of inflow of the waters of one or the other group. p. 22

The thickness of the surface water layer varies greatly from one part of the Arctic Basin to the next. For surface waters of the Eurasian group it is 75 m, whereas for those of the Amerasian group it is up to 50 m. The surface layer of the central type of water is even thinner, and in some years when intermediate water reaches the surface the boundary between the surface and lower intermediate water almost vanishes.

The lower boundary of the surface layer in the Amerasia sub-basin is fairly easy to define, not only by the beginning of the sharp increase in the density gradient but also by the sharp break in the vertical distribution of the main hydrochemical parameters - oxygen, pH, silicic acid, phosphates and nitrates. In the Eurasia sub-basin, the vertical distribution of the hydrochemical characteristics is almost uniform owing to the close genetic relationship between the surface and upper intermediate water, so that it becomes difficult to define the lower boundary of the surface water by these characteristics

The hydrochemistry of the surface water is determined largely by the development and intensity of biological processes and the associated seasonal changes in the chemical composition of the water. It is very difficult to isolate the biological component in the seasonal changes, since the distribution of hydrochemical characteristics in the active layer of the Arctic Basin is greatly influenced by the hydrology of the basin, ie. the surface water circulation system, the intensity of vertical mixing, the depth to which winter convection develops, and so on. Thus in the case of water of the central type the redistribution of the hydrochemical characteristics may be greatly influenced not only by the rate of inflow of other types of water into the area, but also by pronounced vertical cirulation processes [Rusanov, 1975a].

One of the most important factors affecting the chemical composition of the surface water and its seasonal variations throughout the entire Arctic Basin is the high intensity of dynamic processes in the surface layer, which in the high latitudes is also subject to considerable seasonal fluctuation. This is due to one of the principal physical-geographical features of the Arctic ocean, namely the presence of drift ice almost all year round, and also its circulation system.

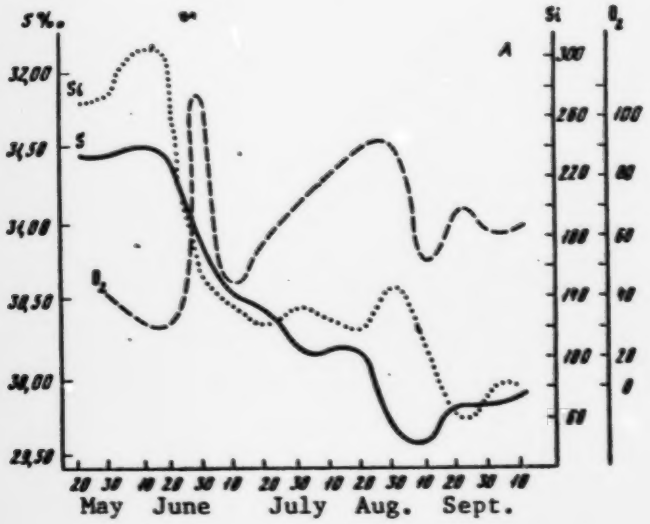
Virtually unbroken ice cover hinders heat and gas exchange between the ocean and atmosphere, which has a marked impact on the gas regime p. 23
of the surface water and on the rate of the processes of biochemical and physical-chemical organic matter regeneration taking place in it. In the autumn-winter period intense heat release to the atmosphere and ice formation cause convective mixing of the water which disturbs its stratification and equalizes the hydrological and hydrochemical characteristics in the surface layer. Furthermore, the concentration

of salts during the ice formation period leads to an increase in the total salinity of the surface water and to a change in the ratio between the salts - enrichment of the water with chlorides and silicates and depletion in carbonates and sulphates. An important part is played in this by the density of the ice cover, since the extremely high salt content of the stationary polynias may make for particularly vigorous vertical circulation. In different parts of the Arctic Basin this may result in various changes in the hydrochemistry of the surface and upper intermediate water. In the central parts of the basin, for example, intense winter convection takes oxygen deep down and brings biogenic elements to the surface, whereas in the Eurasia sub-basin, where there is no Pacific interlayer, enrichment of the surface water with biogenic elements does not occur.

A substantial part of the Amerasia sub-basin is characterized by prolonged circulation and transformation of ice in anticyclonic drift systems. The Canadian part of the basin is one of the most sluggish areas of drift ice, and here there is large-scale extraction of chemical elements from the surface water during ice formation and concentration of them in the ice. The content of biogenic elements in the ice of the Amerasia sub-basin, for example [Mel'nikov, Pavlov, 1978], is close to their content in the surface water of the Eurasian group (see Table 1). In the Eurasia sub-basin, which is characterized by intense removal of ice and hence by rapid renewal of the ice cover, the reverse process occurs to a certain degree, namely salts are transferred to the water from ice brought in from the Amerasia sub-basin. The fairly high content of salts, biogenic elements and organic matter in the various age groups of ice [Mel'nikov, Pavlov, 1978]

and the general outward trend of its movement in the Arctic Basin result in constant irreversible extraction of chemical elements from the Arctic surface water.

Let us examine the seasonal changes in the distribution of hydrochemical characteristics in the active layer of different parts of the Amerasia sub-basin (Fig. 3 a,b) based on data gathered by drifting stations "Severnyi polyus-20" (April--October 1970) and "Severnyi polyus-22" (May--October 1975). Both stations operated within a fairly limited area during the periods in question (see Fig. 1), so any spatial changes in the hydrochemical characteristics due to movement of the stations can be ignored. Furthermore, the working area of each station is situated almost entirely in a single type of water, namely the Canadian type of surface and upper intermediate water in the case of "Severnyi polyus-22" and the Wrangel type in the case of "Severnyi polyus-20". p. 24



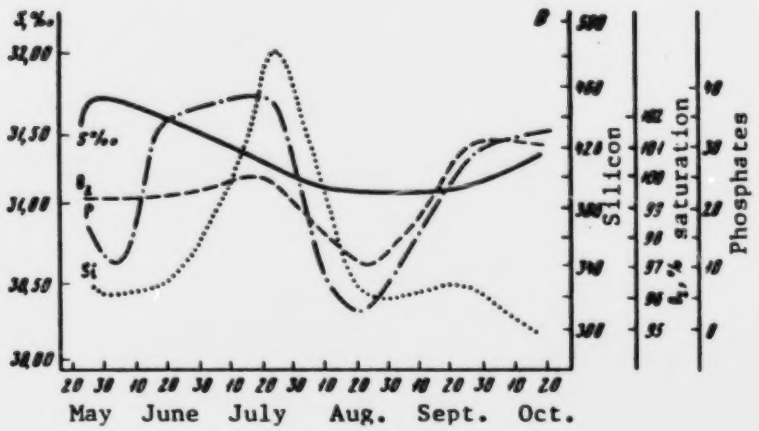


Fig. 3. Seasonal variation in hydrochemical characteristics in the active layer

A - south part of the Amerasia sub-basin (SP-20, 1970); B - central part of the Amerasia sub-basin (SP-22, 1975). Study areas are shown in Fig. 1.

Fig. 3a depicts the curves of variation in silicon content, oxygen saturation of the water and salinity in the area covered by drifting station "SP-20" from May 20th to October 10th at a depth of 10 m. The average silicon content at the end of winter (May-June) based on the data of four stations was 290 micrograms per litre at a salinity of 31.45‰, while differences in silicon content between stations were within the range of accuracy of the method. The surface water is slightly oversaturated with oxygen. p. 25

As can be seen from the data in Tables 2 and 3, the depth to which winter convection develops in this area, where surface water is thoroughly mixed and practically homogeneous in its hydrochemical characteristics, is 40--45 m. The interface between the surface and Pacific water at a depth of 50 m is well defined by the silicon

concentration gradient which is 280 micrograms/l per 10 metres of depth.

In the period from June 17th to June 28th there was an abrupt change in the hydrological situation caused by the onset of intense melting. In a mere ten days the salinity in the surface layer decreased by more than 0.60‰, while the silicon concentration was halved (from 300 to 150 micrograms/litre). However, the change in the silicon content caused by dilution of the surface layer with meltwater remained within the limits of the method used to determine it. It is therefore obvious that the biological processes that had begun were responsible for such a sharp change in the silicon content. This is borne out by the period coincides with a maximum in the saturation of the water with oxygen produced by photosynthesis. The rapid absorption of the silicon shows that the "biological explosion" is mainly due to the mass growth of diatoms which can be explained by the close genetic relationship between the Wrangel type of surface water and the waters of the Chukchi and Bering seas, which are rich in diatom phytoplankton.

The most vigorous burst of diatom growth occurs at the beginning of the Arctic summer (end of June-beginning of July), as is quite clear from the rapid decrease in the content of silicon in the water which is used for the construction of the valves (see Fig. 3a, Table 2). This is followed by a state of relative equilibrium in the consumption and regeneration of silicon from skeletons of dead diatoms. As a result, after a sharp drop in the silicon content of the surface layer at the end of June it remains virtually unchanged until the first third of September, although freshening continues through the entire summer.

In the same period there is a summer maximum in the oxygen content due not only to biological causes but also to a temperature maximum in

the surface water. Between July 10th and August the water temperature rose 0.25° which led to a 0.50 ml/l drop in the solubility of oxygen. The presence of ice cover preventing the discharge of excess oxygen into the atmosphere facilitates accumulation, persistent oversaturation and the formation of a summer maximum. An increase in oxygen content p. 28
from 104% in the first ten days of July to 109% at the end of August corresponds precisely to a change in solubility due to a rise in the temperature of the water at this time. Incipient cooling of the water and intensification of convective mixing in September increases the solubility of the oxygen again and reduces the oxygen content of the water. That the summer maximum in the oxygen content of the water is closely bound up with changes in temperature is indicated by the fact that the absolute oxygen content remains practically the same all through the summer (Table 3). From tables 2 and 3 it can also be seen that the thickness of the active layer in which seasonal changes in the p. 29
hydrochemical characteristics can be observed reaches 30-40 m during the summer growth of diatoms.

The middle of September is marked by second peak in the content of biogenic elements which is associated with the autumn phytoplankton bloom. Between September 10th and 20th the amount of silicon in the surface layer drops markedly from 120 to 60 micrograms/l, although the salinity begins to increase in connection with incipient ice formation. This biogenic element minimum also corresponds to an increase in the oxygen content of the surface water, which bears out the assumption concerning the biological basis of the changes occurring in the chemical composition of the water.

After the brief autumn "biological explosion" there begins a steady increase in the biogenic element content of the surface water.

In addition, during the winter, when convective mixing is intensified and the depth to which it develops increases, the surface water may be enriched with biogenic elements from the underlying Pacific interlayer. All this creates favourable conditions for the growth of phytoplankton in spring.

The seasonal changes in the main hydrochemical characteristics of the surface water in the central part of the Amerasia sub-basin are shown in Fig. 3b. In general they resemble the pattern obtained for the southern regions of the Amerasia sub-basin. However, the higher latitudes involved and the hydrological characteristics of this region make for a number of unique features in the seasonal changes in the chemical composition of the surface water.

At the end of winter (April--June) station SP-22 drifted in an area with depths of less than 2000 m. A characteristic feature of such areas is the relatively high position of the lower and upper boundaries of the Atlantic waters, which causes the water of the Pacific interlayer to rise and sometimes even emerge at the surface [Rusanov, 1974]. This results in salinization of the surface water and its enrichment with biogenic elements. Fig. 3b clearly shows that in the period from May to July there was a marked increase in the content of silicon and phosphates in the surface layer (depth 10 m) caused by the rise of Pacific water.

Starting in June the increase in salinity begins to be offset by the reverse process of freshening stimulated by the melting of ice. It should be noted that although freshening of the surface layer in this area occurs throughout the summer, the more severe climate greatly affects the rate of melting and hence the degree of freshening of the surface water. As a result freshening in summer does not exceed 0.65‰,

whereas in the southern parts of the Amerasia sub-basin it reaches 2.0‰ and more (see Table 2). For this very reason the temperature changes in the surface layer do not exceed several hundredths of a degree, which means that there is no summer oxygen content maximum.

The "biological explosion" in this part of the Arctic Basin begins at the end of July and is accompanied by a rapid decrease in the content of biogenic elements in the water. The attendant marked drop in the silicon content of the water suggests that diatoms are prominent in the phytoplankton of this region. The same period is marked by a considerable increase in the amount of organic carbon in the water and growth of the zooplankton biomass [Mel'nikov, Pavlov, 1978].

The active growing season terminates in about the last third of August. After that, the phytoplankton die-off and mineralization processes become dominant over the processes of biological consumption of biogenic elements, which leads to an increase in their content in the surface layer, with phosphates increasing far more rapidly than silicon. Because of the slow rates of dissolution of the siliceous skeletons of the diatoms, the silicon released into the water can do no more than compensate for the still continuing biological consumption of silicon. Hence the silicon content remains stable in September-October whereas the phosphate content grows rapidly (see Fig. 3b). A further indication of the vigor of oxidation processes at this time is the rapid increase in the pH value (from 8.15 at the end of August to 8.26 in September.

A characteristic feature of the period of maximum biological activity, which is associated with a minimum content of biogenic elements in this region, is the absence of an oxygen maximum. On the contrary, as can be seen from Fig. 3b, there is a minimum during this

period. This is probably due to the seasonal migrations of zooplankton observed at this time [Mel'nikov, Pavlov, 1978]. The amount of oxygen produced by photosynthesis is evidently not enough to compensate for the amount consumed during respiration by zooplankters. This is also borne out by the marked drop in the absolute content of dissolved oxygen (from 8.47 at the end of July to 8.19 ml/l at the end of August) which occurs during this period.

Thus, in the surface waters of the Amerasian group seasonal variation in the chemical composition of the water in the active layer is quite pronounced and is governed not only by biological, biochemical and physicochemical processes but also by the hydrological features of the region.

As regards the Eurasia sub-basin, the absence of year-round observations and the low content of biogenic elements in its waters make it impossible to draw sound conclusions as to their seasonal variations. Probably, both seasonal and annual variations in the content of hydrochemical elements in this part of the Arctic Basin are closely connected with the inflow of Atlantic water. Seasonal changes in oxygen content are particularly noticeable in the surface water in the vicinity of the island shoals of Spitsbergen and Franz Josef Land, where the surface layers contain the "freshest" water of Atlantic origin rich in organic detritus. Table 4 contains the summer and winter figures for oxygen content in the coastal shallows of the Franz Josef Land archipelago.

As can be seen from the data, the summer oxygen content of the surface water in this region is close to 100%. In winter, however, when the water temperature drops, the expenditure of oxygen on oxidation processes in connection with the mineralization of the incoming detritus

is so great that it cannot be replaced by adsorption from the atmosphere, so that there is a constant oxygen deficit of 10%.

Thus after summarizing the results of years of study of the hydrochemical regime of the Arctic ocean water masses we arrive at the following conclusions.

On the basis of the hydrochemical characteristics we can distinguish six types of surface water in the Arctic Basin.

The genesis, distribution area, circulation, chemical and biological features of each type of surface water are determined by the hydrometeorological and ice conditions in the region concerned.

The differences in the hydrochemical characteristics of the various types of water can be traced in all the water masses of the Arctic Basin.

With increasing depth the number of types of water shrinks to three, corresponding to the main water groups in the surface layer.

Seasonal fluctuations in chemical composition are characteristic only of the surface water of the Arctic Basin and, to some extent, of the upper intermediate water of the Amerasia sub-basin.

The nature of the seasonal changes in the hydrochemical composition of each type of surface water is determined by the features of the biological regime, the processes of freezing and melting and water exchange with the polar seas and the Pacific and Atlantic oceans.

LITERATURE CITED

1. Belyakov L.N., Rusanov V.P. Distribution of Pacific water in the Arctic Basin as revealed by biogenic element determinations. - Problemy Arktiki i Antarktiki, 1971, No. 38, pp. 112-115.

2. Gudkovich Z.M. Results of preliminary analysis of deep-water

hydrological observations. - IN: Data of observations conducted on a drifting scientific research station in 1950/51. Leningrad: Morskoi transport, 1955, Vol. 1, pp. 41--46.

3. Gushchenkov E.M. Distribution and metamorphosis of Pacific water in the Arctic Basin. - Okeanologiya, 1964, Vol. 4, No. 1, pp. 36--42.

4. Zhuze A.P., Semina G.I. The general distribution pattern of diatoms in the plankton of the Bering sea and in the surficial bottom sediments. - Dokl. AN SSSR, 1955, Vol. 100, No. 3, pp. 579--582.

5. Mel'nikov I.A., Pavlov G.L. Features of the distribution of organic carbon in the water and ice of the Arctic Basin. - Okeanologiya, 1978, Vol. 18, No. 2, pp. 248--254.

6. Nikiforov E.G., Belysheva E.V., Blinov N.I. The structure of the water masses in the eastern part of the Arctic Basin. - Okeanologiya, 1966, Vol. 6, No. 1, pp. 76--81.

7. Rusanov V.P. Distribution of silicon in the surface waters of the Arctic Basin during winter. - Okeanologiya, 1974, Vol. 14, No. 5, pp.823--830.

8. Id. The hydrochemical regime as an indicator of oceanological processes in the Arctic Basin. - Authorial abridgment of Candidate of Biological Sciences dissertation. Leningrad: Arctic-Antarctic Scientific Research Institute, 1975a.

9. Id. Silicon as an indicator of Pacific water in the Arctic ocean. - IN: Chemical-oceanographic investigations of the seas and oceans. Moscow: Nauka, 1975b, pp. 181--186.

10. Rusanov V.P., Belyakov L.N. Formation of Pacific interlayer water on the shelf of the Chukchi sea. - Tr. Arkt. i Antarkt. nauchn.-issled. in-ta, 1972, Vol. 306, pp. 78--83.

11. Treshnikov A.F. The Arctic reveals its secrets: new data on the bottom topography in the waters of the Arctic Basin. - Priroda, 1960, No. 2, pp. 25--32.

12. Treshnikov A.F., Baranov G.I. Patterns of water circulation in the Arctic Basin. Leningrad: Gidrometeoizdat, 1972, 157 pp.

13. Shirshov P.P. Seasonal phenomena in the life of the phytoplankton of the polar seas in relation to the ice conditions. - Tr. Arkt. in-ta, 1937, Vol. 82, pp. 47--111.

ЛИТЕРАТУРА

1. Беляков Л.Н., Русанов В.П. Распространение тихоокеанских вод в Арктическом бассейне по данным определений биогенных элементов. – Проблемы Арктики и Антарктики, 1971, вып. 38, с. 112–115.
2. Гудкович З.М. Результаты предварительного анализа глубоководных гидрологических наблюдений. – В кн.: Материалы наблюдений на научно-исследовательской дрейфующей станции 1950/51 г. Л.: Морской транспорт, 1955, т. 1, с. 41–46.
3. Гушенков Е.М. Распространение и метаморфизация тихоокеанских вод в Арктическом бассейне. – Океанология, 1964, т. 4, вып. 1, с. 36–42.
4. Жузе А.П., Семина Г.И. Общие закономерности в распределении диатомовых в планктоне Берингова моря и в поверхностных донных осадках. – Докл. АН СССР, 1955, т. 100, № 3, с. 579–582.
5. Мельников И.А., Павлов Г.Л. Особенности распределения органического углерода в водах и льдах Арктического бассейна. – Океанология, 1978, т. 18, вып. 2, с. 248–254.
6. Никифоров Е.Г., Белышева Е.В., Блинов Н.И. О структуре водных масс восточной части Арктического бассейна. – Океанология, 1966, т. 6, вып. 1, с. 76–81.
7. Русанов В.П. Распределение кремния в поверхностных водах Арктического бассейна в зимний период. – Океанология, 1974, т. 14, вып. 5, с. 823–830.
8. Русанов В.П. Гидрохимический режим как показатель океанологических процессов в Арктическом бассейне: Автореф. дис. ... канд. биол. наук. Л.: ААНИИ, 1975а.
9. Русанов В.П. Кремний как индикатор тихоокеанских вод в Северном Ледовитом океане. – В кн.: Химико-океанографические исследования морей и океанов. М.: Наука, 1975б, с. 181–186.
10. Русанов В.П., Беляков Л.Н. Формирование вод тихоокеанской прослойки на шельфе Чукотского моря. – Тр. Арктич. и Антарктич. науч.-исслед. ин-та, 1972, т. 306, с. 78–83.
11. Трешников А.Ф. Арктика открывает свои тайны: Новые данные о рельефе дна в водах Арктического бассейна. – Природа, 1960, № 2, с. 25–32.
12. Трешников А.Ф., Баранов Г.И. Структура циркуляции вод Арктического бассейна. Л.: Гидрометеоиздат, 1972. 157 с.
13. Ширшов П.П. Сезонные явления в жизни фитопланктона полярных морей в связи с ледовым режимом. – Тр. Арктич. ин-та, 1937, т. 82, с. 47–111.

Table 1

Long-term mean characteristics of main types of surface and intermediate water in the Arctic Basin within the boundaries marked in Fig. 1

Main characteristics	Spitsbergen	Severnaya Zemlya	Central	Canadian-Greenland	Wrangel	Canadian
			Surface water (depth 5 m)			
S, ‰	33,16	32,82	30,70	30,84	30,87	30,58
t, °C	-1,80	-1,42	-1,69	-1,70	-1,68	-1,68
Si, мкг/л	75	270	380	250	340	290
P, мкг/л	12	17	36	27	33	26
O_2, мг-Ат/л	0,75	0,74	0,75	0,78	0,79	0,82
O_2, % нас.	98	98	98	101	100	104
pH	8,23	8,13	8,11	8,14	8,21	8,19
			Upper intermediate water (depth 100 m)			
S, ‰	34,55	34,49	33,30	33,75	33,31	32,63
t, °C	-1,29	-0,96	-1,53	-1,53	-1,45	-1,27
Si, мкг/л	160	180	790	350	980	1230
P, мкг/л	22	18	29	26	42	55
O_2, мг-Ат/л	0,70	0,66	0,59	0,66	0,53	0,59
O_2, % нас.	90	90	79	78	70	78
pH	8,04	8,08	8,09	8,11	7,95	8,02

Table 2

Silicon content (μg/l) and salinity (‰) of surface layer of Arctic water in area covered by drifting station SP-20 in 1970

Depth, m	2.V		26.V		10.VI		17.VI	
	S	Si	S	Si	S	Si	S	Si
5	31.38	287	31.44	230	31.55	338	31.39	306
7.5	-	-	31.47	257	31.55	338	31.37	320
10	31.44	270	31.46	267	31.55	307	31.37	303
15	-	-	31.47	294	31.55	308	31.38	285
20	-	-	31.49	253	31.55	289	31.38	292
25	31.44	330	31.47	267	31.55	370	31.38	305
30	-	-	31.47	305	31.55	390	31.65	333
35	-	-	31.49	287	31.56	370	31.65	320
40	-	-	31.46	320	31.58	370	31.84	336
45	-	-	31.49	327	31.58	370	31.92	345
50	31.60	434	31.51	360	31.65	434	32.03	520

Table 2 (continued)

Depth, m	28.VI		10.VII		17.VII		29.VII	
	S	Si	S	Si	S	Si	S	Si
5	30.75	149	30.53	152	30.43	123	30.09	140
7.5	30.75	162	30.53	143	30.44	133	30.10	140
10	30.77	152	30.50	137	30.44	123	30.11	140
15	30.78	151	30.50	144	30.46	125	30.26	140
20	30.79	150	30.55	188	30.50	133	30.31	140
25	30.78	151	30.57	187	30.53	140	30.35	139
30	30.81	167	30.57	193	30.59	150	30.44	145
35	31.41	175	30.58	207	30.84	190	30.53	128
40	31.91	284	30.97	260	31.24	290	30.79	155
45	32.02	458	31.33	319	31.47	350	31.50	38[illegible]
50	32.25	539	31.74	403	31.82	386	31.73	4[illegible]5

Table 2 (continued)

Depth, m	9.VIII		20.VIII		30.VIII		10.IX	
	S	Si	S	Si	S	Si	S	Si
5	30.18	139	30.21	104	29.65	166	29.51	121
7.5	30.18	145	30.21	106	29.66	151	29.51	106
10	30.17	128	30.24	115	29.65	153	29.54	120
15	30.25	128	30.21	123	29.85	151	29.56	118
20	30.47	117	31.03	140	29.83	134	29.54	126
25	30.60	117	31.02	162	30.25	151	29.71	121
30	30.60	130	31.09	183	30.42	167	30.41	134
35	30.77	160	31.18	207	30.59	167	30.49	149
40	31.23	199	31.35	208	31.32	344	30.76	212
45	31.87	340	31.58	296	31.78	435	31.10	282
50	32.10	410	32.03	440	31.89	487	31.65	386

Table 2 (continued)

Depth, m	22.IX		29.IX		9.X	
	S	Si	S	Si	S	Si
5	29,86	93	29,80	118	29,89	105
7,5	29,85	65	29,80	83	29,89	102
10	29,85	60	29,80	78	29,89	86
15	29,85	58	29,80	80	29,90	97
20	29,85	58	29,80	77	29,90	116
25	29,85	58	29,80	84	29,90	122
30	29,90	72	30,00	120	29,90	101
35	30,07	93	30,78	140	30,53	110
40	30,99	194	31,00	167	30,78	146
45	31,82	317	31,18	328	31,03	234
50	31,50	353	31,36	423	31,28	325

Table 3

Oxygen content in the surface layer of Arctic water in area covered by drifting station SP-20 in 1970

Depth, m	20.V		26.V		10.VI		17.VI		28.VI		10.VII		17.VII		29.VII	
		%		%		%		%		%		%		%		%
5	0,79	104	0,80	106	0,81	107	0,78	104	0,82	106	0,81	107	0,80	104	0,80	105
7,5	-	-	0,79	105	0,77	102	0,76	101	0,82	109	0,79	104	0,80	106	0,81	107
10	0,78	104	0,78	104	0,78	103	0,78	104	0,84	111	0,79	104	0,80	106	0,81	107
15	-	-	0,79	104	0,76	101	-	-	0,81	107	0,79	104	0,80	106	0,80	106
20	-	-	0,79	106	0,77	103	0,75	99	0,82	108	0,79	104	0,80	106	0,80	107
25	0,78	103	0,79	104	0,77	102	-	-	0,82	107	0,79	104	0,79	105	0,81	107
30	-	-	0,79	104	0,77	102	0,74	98	0,81	107	0,78	104	0,77	102	0,81	107
35	-	-	0,77	102	0,77	102	0,73	97	0,80	106	0,77	102	0,70	93	0,80	106
40	-	-	0,78	104	0,76	102	0,75	100	0,75	100	0,73	92	0,70	93	0,80	106
45	-	-	0,78	103	0,77	103	0,76	102	0,68	91	0,75	100	0,69	91	0,79	96
50	0,76	102	0,77	103	0,76	102	-	-	0,66	89	0,72	96	0,67	90	0,73	94

Depth, m	9.VIII		20.VIII		30.VIII		10.IX		22.IX		29.IX		9.X	
		%		%		%		%		%		%		%
5	0,81	108	0,83	110	0,82	108	0,81	107	0,81	107	0,81	106	0,81	106
7,5	0,81	107	0,83	109	0,80	106	0,80	106	0,81	107	0,80	106	0,81	107
10	0,81	107	0,83	109	0,82	109	0,80	105	0,81	107	0,80	106	0,81	107
15	0,80	107	0,83	110	0,82	109	0,80	105	0,81	106	0,81	106	0,81	106
20	0,80	107	0,83	110	0,82	109	0,79	104	0,81	107	0,81	107	0,80	106
25	0,80	107	0,83	110	0,82	108	0,80	105	0,81	107	0,81	107	0,80	106
30	0,79	105	0,82	109	0,82	109	0,82	108	0,81	106	0,80	105	0,80	106
35	0,78	103	0,80	110	0,81	107	0,80	107	0,82	108	0,79	106	0,82	109
40	0,78	103	0,80	107	0,70	101	0,79	106	0,76	100	0,77	102	0,80	105
45	0,71	96	0,77	103	-	-	0,76	102	0,70	95	0,72	96	0,76	102
50	0,68	92	0,71	96	0,69	93	0,74	99	0,69	92	0,70	93	0,73	97

Table 4

Oxygen content in different seasons in surface water of the Spitsbergen type

Depth, m	August		October		April	
	mg-at/l	%	mg-at/l	%	mg-at/l	%
5	0,75	98	-	-	0,70	93
10	0,74	99	0,70	93	0,68	90
25	0,73	101	0,68	90	-	-